ENGINEERING HERITAGE AUSTRALIA

ENGINEERING HERITAGE VICTORIA

NOMINATION

for

ENGINEERING HERITAGE RECOGNITION

GOULBURN WEIR & ADJOINING WORKS

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Cover photograph: Aerial view of Goulburn Weir and the Stuart Murray canal.

2. Introduction

The Goulburn Weir was originally built under the auspices of the Victorian Government between 1887 and 1891 along with a part of related irrigation works that Heitage Auswere subsequently completed and then augmented in succeeding decades. The weir and its related works were deemed a national work at the time of their inception and constituted the first large scale irrigation works to be undertaken in Australia at the time[1] [2]

The weir structure was further stabilised, and the majority of its former vertical water control gates replaced with modern radial type gates in the 1980s. This refurbishment took particular care to retain the heritage character and appearance of the original structure, including reconstructing and making operational two of the original vertical gates. The refurbished weir is in a sound conditions and continues to fulfill its original purpose.

The Goulburn Weir diverts an average of 1768 Gl a year[3] to irrigate land in the north and north-west parts of Victoria, the latter now extending as far west as the township of Boort.

2. Heritage Award Nomination Letter

The Learned Society Advisor

Engineering Heritage Australia

Engineers Australia

11 National Circuit

BARTON ACT 2600

Name of Work: Goulburn Weir and Adjoining Works

The above work is nominated to be awarded an Engineering Heritage National Marker.

Location: Goulburn River, Central Victoria.

Owner: Goulburn-Murray Water on behalf of the State of Victoria

Operator: Goulburn-Murray Water

Owner's Agreement: The owner has reviewed this nomination and is supportive of it.

Access: The Goulburn Weir site and its superstructure is publicly accessible.

The Nominating Body for this Nomination is Engineering Heritage Victoria.

Guy Hodgkinson

Chair

Engineering Heritage Victoria

Date: 4 May 2021

3. Heritage Assessment

3.1 Basic Data

Location:	Goulburn River, Central Victoria
Nearest town:	Nagambie
Local Govt. Area:	Shire of Strathbogie
Owner:	Goulburn-Murray Water on behalf of the State of Victoria
Function:	Diversion of river water for land irrigation
Designer:	William Henderson, AMICE, Victoria Water Supply Dept.
Main contractor	Cornwell, Darling & Co.
Year started	1887
Year completed	1891
Basic form	Masonry wall surmounted by water control gates
Condition	Sound and well maintained
Modifications	Major wall stabilisation works and new rotary gates 1980-87

3.2 History

3.2.1 Evolution[4] [5]

The Goulburn weir was originally constructed between 1887 and 1891 as the primary element of a national land irrigation scheme based on redirecting water from the Goulburn River, a major tributary to the Murray River from the Victorian side. A first firm proposal for the construction of a weir to divert water from the Goulburn River was contained in an 1880 report of the Victorian Water Conservancy Board, and again in a report four years later. This was then further promoted by the Echuca & Waranga Waterworks Trust with the newly formed Water Supply Department. In 1884 a Royal Commission on water supply was setup under the chairmanship of Alfred Deakin with engineer, Stuart Murray, who had hitherto been engineer to the EWWT, as secretary. This led to the revolutionary Irrigation Act of 1886 that inter alia restricted riparian rights of landowners by vesting in the crown the sole right to the use and control of surface waters and for the undertaking of national irrigation headworks. The Act also reorganised the Victorian Water Supply Department and Stuart Murray was appointed as its engineer-in-chief.

To progress the Goulburn scheme in particular, a dedicated Board was set up, comprising the then secretary of the Water Supply Department and two independent engineers. In 1886 the Board duly recommended the establishment of a weir 12 miles (19 km) upstream (measured along the river's course) from Murchison, to be constructed of concrete masonry with its downstream face protected by ashlar work. A series of metal gates on top of the structure would then regulate the river flow to maintain an upstream water level sufficient for the desired water diversion.

Based on the Board's report the Victorian parliament authorised construction of the weir as a national work under the 1886 Irrigation Act. Detail design work and the preparation of contract documentation commenced immediately by the Water Supply Department under Stuart Murray as its Engineer-in Chief, with William Henderson, AMICE as design engineer and superintendent. The initial design work was informed by river gauging data from 1881 to 1886. (The methodology is described in some detail in Murray, 1893.) A contract for construction was entered into in early 1887 with Messrs Cornwell, Darling & Co., and the work at the weir site along with 24 miles (38.5 km) of the western main canal was completed in 1891. Delays and additional construction costs were incurred due to unusually high and protracted floods in the winters of 1887 and 1889 and a decision to make greater provision for flood flows and to include water turbines to power the floodgate mechanisms and to provide electric lighting for night-time operations.

The Goulburn Weir was the first major water diversion structure built for irrigation development in Australia.

3.2.2 Description of the Original Weir and Immediate Related Works[6]

The weir was designed to raise the summer water level by 45 ft (13.7 m), giving a resultant depth of about 50 ft (15 m) for the raised still water surface above the riverbed. The underlying rock was described as 'soft upper Silurian shale formation with alternating beds of sandstone and pipe clay standing on edge diagonally across the stream'.

The as constructed weir measured 695 ft (212 m) long over the abutments and comprised of a single long straight section with a short western end section aligned at about 60º to the former. It was constructed of large, cement mortar jointed, concrete masonry blocks backed on the downstream side with steps of course granite blocks, each notched into the preceding course. The upstream face of the wall was rendered with a thick coat of cement mortar. All concrete was hand mixed on site using locally sourced sand and aggregate. The granite blocks were quarried from nearby Mt Black.

Six tunnels in the lower part of the wall were provided to permit the passage of the 'ordinary flow' of the river as construction proceeded. Temporary coffer dams were utilised to exclude water whilst the lower parts of the wall were constructed, starting from one side, then moving to the other and then the middle sections. When the weir wall was completed, large cast-iron sluice gates on the tunnel upstream portals were permanently closed. (The tunnels were later further sealed with concrete plugs).

The flood flows experienced during construction exceeded anything previously recorded and overtopped the partly completed works, but reportedly no significant damage was sustained to the previously installed concrete and granite.

The waterway above the weir sill was occupied by 21 flood gates that could each be lowered into drained recesses in the weir wall. Each gate comprised of a wrought-iron

frame with cast-iron infill plates and measured 20’ 11” (6.4 m) x 10’ 3” (3.1 m) high and weighed about 7 ton (7 t). The gates were hung on rods linked to lifting screws with a gunmetal nut on each screw centred in a horizontal bevel gear. Three 30½” (775 mm) Leffel ‘double turbines’ housed in wells within the weir wall were liked by drive shafts and gearing on an upper walkway such that any turbine or combinations thereof could be engaged by clutches to operate (raise or lower) any individual gate. In addition, a geared winch on the upper walkway in front of each gate could be used to manually operate the gate as a back-up to the turbines. The head available to work the turbines could vary between 3 to 13 ft (0.9 to 4 m) – the latter for the normal upstream water level with the gates ‘up’ and the former during flood flow conditions with the gates lowered. The available power from each water turbine correspondingly ranged from 3 to 27 hp (2 to 20 kW).

As the gates could need to be adjusted at night-time to accommodate any substantial change in river flow or a flood flow, a fourth smaller 23-inch (585 mm) Leffel water turbine was setup in another well in the western end of the weir wall and arranged to drive an arc lighting dynamo housed in a small masonry building. Five 2000 cp (2000 cd) Brush carbon-arc lamps were mounted on posts along the upper walkway to illuminate the gate operating mechanisms. Calculations by M Pierce using information from a contemporary Leffel turbine catalogue indicate that full operation of the five arc lights would only have been practicable with the upstream water level being close to its ‘normal’ operating value, however, further line shafting permitted the lighting turbine’s output to be augmented by one or more of the turbines used for operation of the flood gates.

The electrically lit weir became a tourist attraction, particularly when the river was in high flow with water then passing over the gates and cascading down the granite steps. In this connection, it is surmised that the weir was routinely illuminated in the evenings for the pleasure of visitors. The hydroelectric system, although small, was amongst the earliest in the State.

Sluice gates on the upstream openings to the water turbine wells and operable from the upper walkway were used to admit water to each well whilst a handwheel above each turbine on the upper walkway enabled adjustment of the turbine output power via its moveable inlet guide vanes. The upper operating walkway ran the full length of the weir and was supported on cast-iron columns fixed to the wall sill.

Connected to the weir as a continuing structure were the regulators for the western and eastern main offtake channels. The western regulator was fitted with fourteen, 10 ft wide x 7 ft high (3 X 2 m) vertical pin type gates whilst the eastern regulator had four such gates. Each gate was constructed as a wrought-iron frame with timber infill and was fitted with a vertical central shaft with a quadrant gear and worm wheel on a cast-iron pedestal positioned on the operating walkway. By this means, the individual gate openings could be manually adjusted to control water flow into the offtake channel. In the event, the eastern channel was later constructed further to the east and the original provision at this end of the weir was removed and the area later backfilled.

The weir works included approximately 120 500 cu yds (92180 m^3) of excavations, 15 300 cu yds (11700 m^3) of cement concrete and 72 000 cu ft (2040 m$^{3)}$ of coursed granite masonry. The total contract cost for construction of the weir and other related works not included in the original contract was £106 000, or roughly $11 M present

day terms. Full supply water level upstream of the weir was first achieved in the third quarter of 1891 with the impounded water forming Lake Nagambie.

Concurrent with the construction of the weir, 25 miles (38.5 km) long western main offtake channel was excavated. This channel was designed to carry up to 103400 cfm (2.9 Ml/min). The channel bed was made 110 ft (33.6 m) wide with side slopes of 1.5 to 1 and a full supply water depth of 7 ft (2.1 m). It followed the land contours with a bed gradient of 6” per mile (95 mm per km). The western main channel delivered water into the Waranga reservoir – Waranga Basin – located near Rushworth and about 20 km to the north-east of the weir site. This reservoir when completed shortly after the weir was built was formed by constructing a 4.25 miles (6.8 km) long earthen embankment around the low side of the former Waranga swamp to create a 9000 million cu ft (255 Gl) storage capacity. A main outlet channel, the Waranga Western Channel was then built and progressively extended to service irrigation districts in the north-west of the State. The storage volume of the Waranga Basin was increased to 432 Gl between 1915 and 1921 by raising the original earthen embankment.

The eastern main channel to serve the planned Shepparton irrigation district was not constructed until early in the twentieth century when the take-off location from the impounded water was relocated further to the east.

The original western main channel from the Goulburn Weir was renamed the Stuart Murray Canal in 1957 by the minister for water supply concurrent with the then official opening of the Cattanach Canal that augmented supply from the weir to the Waranga Basin. The latter canal draws from the west side of the weir impoundment approximately 0.5 km upstream and has its radial gate regulating structure adjacent to where the canal crosses under the Goulburn Weir – Murchison Road.

3.2.3 Subsequent modifications and upgrade works[7]

In 1960 an ‘emergency’ petrol engine was installed at the eastern end of the superstructure walkway as a backup to the water turbines for operation of the vertical gates. A year later electric motor drive equipment was installed above the turbine wells at the end of the long strait section of the weir wall to replace the water turbine drives for operation of the vertical gates. It is assumed that this was done when mains electricity supply (from the then SECV) became available and that the water turbine powered electric arc lighting was replaced by mains operated lighting at around the same time. Thereafter, the Leffel turbines would have become redundant, although they were left in situ.

The six original diversion tunnels in the base of the weir wall were plugged with concrete in 1964 as a precaution against possible failure of the permanently closed cast iron sluice gates due to corrosion.

In 1967 four new radial gates were installed in the middle of the western main channel (Stuart Murray Canal) regulator structure and the remaining metal framed, timber clad vertical pin butterfly gates permanently closed. The latter old gates were reinforced with concrete in 2016 and their former worm and quadrant manual actuation pedestals subsequently removed.

A major rehabilitation of then 90 years old weir structure was undertaken from 1980 to 1987 by the then Rural Water Commission to stabilise the whole gravity-based

water retaining structure and to modernise its flood gates. This was a particularly challenging project, requiring as it did that the works be carried out such that the weir remained fully operational throughout. It enabled the life of the heritage listed Goulburn Weir to be extended by an estimated 50 years. The rehabilitation was also planned and executed to be sympathetic to the heritage significance of the original structure.

Investigations revealed that serious scouring of the riverbed at the downstream toe of the weir had occurred. A failure analysis indicated an unacceptably low factor of safety for a sliding failure on the sloping joint planes of the underlying strata. Various potential remedial measures were assessed with the result that a concrete plinth was constructed along the toe, a process made difficult due to inability to safely dewater the large scour hole. Following some initial trials, a total of fifty-three 22 m long stressed anchors, angled at 30º to the vertical and spaced at 1.75 m nominal centres were installed along the length of the new concrete plinth which then acted as an anchoring beam as well as protecting the weir toe from undercutting.

Prior assessments of the vertical flood gates and the associated cast-iron support piers using a needle beam cofferdam revealed serious deterioration of many of the gates and their fixed guides along with corrosion damage to the lower parts of the C I piers. On this basis it was determined that the existing vertical gates and the C I piers could not be practicably restored and should therefore be replaced along with the associated superstructure. The 19 vertical gates in the main part of the weir were replaced with 9 radial gates, each measuring 12.87 m wide by 3.65 m high with a 4 m radius. To support the new radial gates and their trunnion axles along with new overhead infrastructure, new shaped reinforced concrete piers were constructed on the downstream face and secured with 25 m long ground anchors. The work was carried out progressively using a timber needle beam cofferdam spanning three old gate openings at a time.

Each new radial gate was operated by an electric motor driving a rope drum on each side of the gate. Adjustment of each gate by the operator could be either via a manual handwheel or by pushbuttons controls for the electric actuators located both at the gate and in the control building. In addition, any of the five central gates could be preselected for automatic control to maintain a pre-set upstream pool water level.

The old vertical gates were removed, and their former retraction slots filled with concrete along with reshaping of the weir crest. The concrete filling of the gate slots served to largely restore watertightness of the upstream face of the weir structure. A new superstructure for access to the gate operating gear and for a public walkway across the weir was supported off the new concrete piers. Provision was also made for placing stop logs upstream of each radial gate to facilitate future maintenance. A travelling, electrically operated gantry crane was also installed for placing and removal of stop logs and performing other maintenance tasks.

With the new radial gates in the main straight section of the weir wall sufficient to handle design flow and flood flow conditions, the two remaining vertical gates in the angled part of the weir wall adjoining the western abutment were reconstructed to match the form of the original gates. Their mechanical raising and lowering machinery was refurbished and an electric motor drive for same installed inside the former dynamo building. This preserved a representative section of the original heritage infrastructure so that the arrangement and operation of the old gates could be

observed and interpreted. A provision for placing stop logs in front of the restored gates was added to facilitate future maintenance of them.

An assessment at the time concluded that it was not practicable to refurbish any of the former turbines given their seriously deteriorated condition and/or missing components. The turbine wells however remain, leaving open the possibility of installing a suitable water turbine in the future.

Whilst the new concrete piers for the radial gates and to support the new operating deck and public walkway intrude onto the stepped granite downstream face of the original weir structure, they have been carefully shaped and kept narrow to minimise their visual impact and the majority of the original granite facing remains intact. Specialist architectural and heritage consultants were retained to advise the project team on the remedial works so as to maximise retention of the heritage aspects.

The weir rehabilitation project was accorded an Engineering Heritage Excellence Award by the Victoria Division of the Institution of Engineers Australia (Engineers Australia) in 1988. The judges were particularly impressed with how execution of the challenging project was achieved without interruption to the function of the weir and also took particular note of the care taken to retain the heritage aspects of the structure, including in particular the rebuilding of two of the vertical gates and restoring their mechanical operating mechanisms.

3.3 Heritage Recognition

In 2017 the Goulburn Weir and its related works was accorded international recognition as a heritage and current working structure by the International Commission on Irrigation and Drainage (ICID).

In 1923 the national significance of the Goulburn Weir was reflected in its being depicted on reverse side of the nation’s then Half Sovereign (Ten Shilling) bank note.

4. Assessment of Significance

4.1 Historical Significance

The Goulburn, constructed between 1887 and 1891, is significant as the first such major structure built for land irrigation and stock water supply in Australia. At the time of its construction, it was deemed to be a ‘national work’.

4.2 Historic Individuals

The original design and preparation of contract documentation and superintendence of the construction was entrusted to engineer William Henderson, AMICE, who was engineer to the independent Board that was established following the 1884 Royal Commission and then worked for the Victorian Water Supply Department. The Department’s Engineer-in-Chief was Stuart Murray who along with his other responsibilities was actively involved in the Goulburn Weir project.

4.2.1 William Henderson[8]

William Henderson was born in Glasgow, Scotland, in 1854, as the son of engineer-architect James Henderson. He served a pupillage with his father and then was articled to Messrs Smith & Wharrie, engineers and surveyors and subsequently served for five years as an assistant to James Wilson, engineer to the Water Trust of Greenock. Henderson entered private practice in his own right in 1879 and in the following seven years designed are supervised waterworks for various public clients as well as assisting Messrs Wilson and Gale on a number of large public waterworks projects for Glasgow and other centres. He became an Associate Member of the Institution of Civil Engineers (AMICE) in 1885.

In 1886 Henderson emigrated to Victoria and undertook investigation and reporting on irrigation projects for the then Royal Commission on Water Supply. This led to his appointment to the Victorian Water Supply Department to carry out the detail design, contract documentation and superintending the construction of the Goulburn Weir. Afterwards, Henderson was involved with investigations for the supply of water for domestic and stock purposes in the Mallee district. He retired from the Water Supply Department in 1895 to return to private practice in association with a Mr J B McKenzie, MICE, and was engaged on designing hydroelectric works for mining ventures. Henderson was made full member of the Institution of Civil Engineers in 1896 with his application endorsed by eminent Victorian engineers including George Gordon, Maurice Kernot and William Thwaites.

In 1897 he suffered a paralysis condition from which he made only a short-term partial recovery. He died at the age of 44 at his brother's residence near Dromana in December 1898.

4.2.2 Stuart Murray[9]

Stuart Murray was born in 1837 in Dundee, Scotland, the second son of James Murray and his wife Jessie, nee Simmers. After studying engineering for two years at Madras College, St Andrews he emigrated to Victoria in 1855, attracted by the opportunities created by the rich gold discoveries. Based in Kyneton he continued his engineering studies privately and duly obtained formal qualifications as a land and mining surveyor, and civil engineer. Murray spent six years as a government mining surveyor in Daylesford and later surveyed mining leases and settlements in northern Victoria. He also carried out work for the then Victorian Water Conservancy Board under George Gordon and Alexander Black that gave him experience and an insight into water supply issues.

In 1882 Murray became engineer to the United Echuca and Waranga Waterworks Trust, the then largest such rural waterworks trust for supply of stock and domestic water established under the 1881 Water Conservancy Act that had originated from the work of Gordon and Black. Two years later Murray was appointed by Alfred Deakin as secretary to the Royal Commission on Water supply which led to the epoch making 1886 Irrigation Act. Inter alia the Act included the reorganisation of the Water Supply Department and Murray was appointed as its Engineer-in-Chief and under the Act's provisions had responsibility for implementing its vesting in the Crown the sole rights for the use and control of practically all surface waters. This concept was way ahead of European practice and Murray's role was later recognised by him being made Chevalier du Merite Agricole by the French government.

As Engineer-in-Chief of the Water Supply Department, he had overall responsibility for the development of the Goulburn Weir and its related works. He was also involved

with the Upper Coliban reservoir, the Laanecoorie Weir on the Loddon River and early work on Geelong's water supply along with various other irrigation projects in the State.

In 1905, under the leadership of George Swinburne, the then minister for Water Supply, a new Water Act was passed that abolished the control of irrigation from all but one of then multiplicity of rural trusts and set up the State Rivers and Water Supply Commission to assume this responsibility. Murray was appointed as the Commission's first chairman in 1906.

Murray maintained his involvement with his original training in mine surveying, land surveying and water supply engineering and was a member of their respective boards. He was a founding member of Victorian Institute of Surveyors, a member Melbourne University's Faculty of Engineering and a Member of the Institution of Civil Engineers (MICE). After retirement in 1908 he remained involved with public affairs. Murray died in April 1919, survived by six children.

Murray's 'Descriptive Memorandum on The Goulburn Weir and its Dependent System of Works' that was published by the Victorian Government in 1893, replete with numerous diagrams and engineering drawings, provides a definitive technical record of the original work. It has formed the basis of the 'Description of the Original Weir and its Immediate Related Works' in this nomination document. An illustrated article based on the same document appeared in an issue of the U K published serial; 'The Engineer' in the following year[10]

4.3 Creative or Technical Achievement

The Goulburn Weir as the first such structure in Australia for the diversion of large quantities of water for irrigation purposes, was a major technical achievement that operated successfully from its completion in 1891.

4.4 Research Potential

The original construction of the weir and its related works is well documented, including in particular in Murray, 1893, and although less public, the 1980's major refurbishment is similarly well documented. In this context there does not appear to be a great scope for further research in relation to engineering heritage aspects, however, some 'niche' areas such as the innovative use of water turbines to power the vertical gate mechanisms may offer further research opportunities.

4.5 Social / Societal

The Goulburn Weir and its related works had a large social and societal impact by enabling more intense agriculture and resultant boost to the State's economy through the irrigation water it provided over extensive otherwise dry land regions to the north and northwest.

The weir, by raising the upstream water level created Lake Nagambie which afforded and continues to afford many water based recreational opportunities for people both in the local region and more widely. In particular, the Lake is used as a State venue for rowing regattas and water-skiing competitions.

4.6 Rarity

Since the Goulburn Weir was built, many other weirs have been constructed to divert natural stream flows for both urban and rural water supplies and for land irrigation purposes. It is therefore not rare per se.

4.7 Representativeness

The Goulburn Weir is representative of other such structures, both at the time it was originally built and in its refurbished form that utilises radial gates.

4.8 Integrity / Intactness

The Goulburn Weir has been maintained by the various government bodies charged with responsibility for it over its now 130 years lifespan and continues to serve its original function. The stabilisation works performed by the Rural Water Commission in 1980s were aimed at extending the life of the structure whilst measuring up to modern safety standards.

4.9 Statement of Significance

The Goulburn Weir is significant on a national level as the first large scale weir in Australia constructed for the purpose of land irrigation.

5. Interpretation

At the time of preparation of this Engineering Heritage Recognition nomination, Goulburn-Murray Water are in the process of developing the content for a series of new public interpretation panels at the weir site. It is envisaged that these will include information about the history of the weir and its construction along with information on the irrigation scheme that it supports. In this context, it may be sufficient to simply add an Engineering Heritage marker disc to the new GMW public information signage dealing with the weir or incorporate the disc form into the panel content.

6. Acknowledgements, Authorship and General Notes

6.1 Nomination Preparation

This nomination was originally started by Owen Peake in 2020 and included the upstream Kirwins and Chinamans bridges. Whilst that latter bridges have engineering heritage significance in their own right, they were not directly a part of the Goulburn Weir and its irrigation related national works. Accordingly, the two bridges have been omitted from this nomination. They may now well be the subject of a future nomination(s).

By agreement with Owen Peake, Miles Pierce took over finalisation of the Goulburn Weir engineering heritage recognition nomination task in early 2021 together with ongoing liaison with Goulburn-Murray Water personnel.

7. Photographs and Illustrations

See supplementary document.

8. References

[1] L R East, Irrigation and Water Supply in Victoria, in One Hundred Years of Engineering, Journal of the Institution of Engineers, Australia, Vol. 6, 1934, pp289-393.
[2] P J Hallows, The History of Irrigation in Australia, Proceedings of the 19th Australasian Engineering Heritage Conference, Mildura, 2017.
[3] Goulburn-Murray Water, Welcome to Goulburn Weir, visitor information sheet, 2012.
[4] L R East, op cit.
[5] Stuart Murray, The Goulburn Weir and its Dependent System of Works – A Descriptive Memorandum, Government of Victoria, 1893.
[6] Ibid.
[7] Rural Water Commission, Submission for Engineering Excellence Award – Rehabilitation of Goulburn Weir, 1988.
[8] Obituary notice, William Henderson, Minutes of the Proceedings of the Institution of Civil Engineers, Vol. 136, Issue 1899, pp 350-351.
[9] V Yule, Entry for Stuart Murray in Australian Dictionary of Biography, MUP, 1974.
[10] The Engineer, 3 August 1894

9. Change Control

The document change control hereunder has been restarted for this revised scope and changed primary author nomination.

This item will be relocated to last page when document is finalised.

Version 0	26 March 2021	
Version 1	10 April 2021	(incorporates comments by S McGrath / T Court)
Version 2	21 April 2021	(incorporates comments by S Wikman / GMW)
Version 3	05 May 2021	(nomination letter plus format adjustments